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Relationship between velvet antler weight and liveweight in red deer (*Cervus elaphus*)

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Abstract The allometric relationship ($Y = AX^b$) between velvet antler weight (Y) harvested at 2, 3, and 4 years of age and the respective winter lean liveweight (X), was examined in 145 farmed red deer stags (*Cervus elaphus*). The stags which were the progeny of 10 sires, were born in 1982 and 1983. The allometric coefficients (b) for the 1982- and 1983-born stags were 2.4 and 1.7 respectively which indicated that velvet antler was late maturing relative to winter lean liveweight. Sire had a significant effect on the scaling factor (A, $P < 0.05$) of the allometric equation, which indicated that over the liveweight range in this study, there was up to a 30% difference in velvet antler weight adjusted for winter lean liveweight for stags from the different progeny groups. The sire effect on the relationship between velvet antler weight and winter lean liveweight indicates the possibilities for selection of genetically superior sires for velvet antler production relative to winter lean liveweight.

Keywords red deer; *Cervus elaphus*; velvet antler; liveweight; allometry

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INTRODUCTION

The antler cycle in temperate species of deer is an annual series of events with antlers being grown, mineralised, and cast in a well-defined sequence (Goss 1983). Following casting of the hard antler in spring (for red deer; *Cervus elaphus*), the new antler grows in the form of vascular epidermal cartilaginous tissue with soft epidermal hairs, defined as velvet antler (Wislocki 1942). Subsequent mineralisation of the cartilaginous tissue and stripping of the epidermal layer occurs under the influence of a rising concentration of testosterone in early autumn (Fennessy & Suttie 1985).

The annual regeneration of antlers in deer is a unique phenomenon in mammalian species, in that it constitutes the regeneration of a complete organ. Consequently, an investigation of the allometric relationship offers potential insights into some of the underlying biological relationships between antler weight and liveweight. In this respect, Huxley (1931) used the allometric equation to describe the relationship between hard antler weight and body weight in mixed-aged European red deer (*Cervus elaphus*; $n = 527$). The allometric coefficient reported between hard antler weight and eviscerated body weight was 1.6, indicating that the weight of hard antler increased at a relatively greater rate than body weight. In a more comprehensive study based on data from 1700 German red deer stags shot in the Harz mountain district, Schröder (1983) proposed a 2-phase allometric relationship between antler weight and body weight, with allometric coefficients of 1.7 and 1.9 in immature (less than 5 years) and mature stags (5 years or older) respectively.

The positive relationship between velvet antler weight and body weight suggests that there would be considerable advantage in farming larger strains of deer for velvet antler production (Fennessy 1989a,b). As a result, the relationship between velvet antler weight and liveweight may have implications for improving velvet antler production and also developing selection strategies within the herd. To date, this approach has been limited by the lack of studies relating velvet antler weight to liveweight in farmed deer, particularly when considering different sire lines.

The aim of this study was to examine the effect of sire and year of birth on the allometric relationship between velvet antler weight and liveweight in individual stags.

MATERIALS AND METHODS

One hundred and fourty-five red deer stags, raised for commercial velvet production at Mt Hutt Station, located in the mid-Canterbury region of the South Island of New Zealand, had velvet antler weight and liveweight recorded over 3 successive years. The stags, born in 1982 and 1983, were the progeny of 5 and 7 sires, respectively, with 2 sires common to both years. Foundation animals originated from the Rakaia region (Banwell 1972) of the South Island.

Each year, hinds were randomly allocated to single-sire mating groups of up to 50 hinds for c. two oestrous cycles (i.e. 36 days), from late March. After mating, all hinds were managed as one herd until October, when they were separated into calving groups based upon sire. Calving occurred in December and calves were individually tagged before weaning at 3–4 months of age. Hinds were randomly allocated to sire mating groups in each year. Within year-of-birth cohorts, stags were managed as a single group from weaning until 4 years of age. Sires were selected on phenotypic liveweight and velvet antler weights, although these measurements were not recorded for further analysis.

Velvet antler was harvested at 2, 3, and 4 years of age following a commercial procedure and in accordance with the New Zealand Animal Protection Act (1960). Velvet antler from 2-year-old stags was harvested when the tip of the velvet antler was rounded and, if the trez tyne was present, before it became prominent. Velvet antler was harvested from the 3- and 4-year-old stags, when the bulb that forms the royal tynes was slightly indented and the tips of the bez and trez tynes were still rounded (Moore 1984; Muir et al. 1987). This stage of antler growth was generally achieved 55–70 days after casting of the previous antler button. For stags with damaged antlers, total velvet antler weight was assessed as twice the weight of the undamaged antler.

The stags were weighed in July of each year when they had minimal reserves of fat (winter lean liveweight; Drew 1985). Thus, liveweights were first recorded at 20 months (July), with successive liveweights recorded annually for all stags. Data collected from stags that died during the experimental period were discarded.

The relationship between velvet antler weight and winter lean liveweight was assessed using the allometric equation $Y = AX^b$, where A is the scaling factor, Y the velvet antler weight (kg), X the winter lean liveweight (kg), and b the allometric coefficient. This equation was fitted in the linear form after $\log_{10}$ transformation, which minimised the positive relationship between the means and variance. The allometric relationship between log velvet antler weight and log liveweight was initially examined with a model that included terms for sire, year of birth, log liveweight, all first-order interactions, and animals within sire. The latter term was used as the error to test sire effects and the interactions of sire × year of birth and sire × log liveweight, whereas the year of birth main effect and its interaction with log liveweight was tested using the within-animal error term. Non-significant terms ($P > 0.05$) were sequentially dropped from the model to obtain the final model which contained terms for sire, year of birth, log liveweight, the interaction of year of birth × log liveweight, and animals within sire ($P < 0.05$). This model examined the relationship between velvet antler weight and liveweight on a within-stag basis at 2, 3, and 4 years of age.

RESULTS

Table 1 presents mean velvet antler weights and liveweights for stags at 2, 3, and 4 years of age for the two cohort groups. In both cohort groups, velvet antler weights and liveweights increased with the age of the stags. The velvet yield of the 1983-born 2-year -olds was about 20% higher than that of the 1982-born animals. This was associated with a higher coefficient of variation in the 1982 cohort group.

Table 2 shows the within-animal allometric relationship between log velvet antler weight and log liveweight, assessed over 2, 3, and 4 years of age. Sire had a significant effect on the scaling factor ($P < 0.05$), whereas year of birth had a significant effect on both the scaling factor and the allometric coefficient ($P < 0.05$). The allometric coefficients showed that velvet antler weight was later maturing in the stags born in 1982 (b = 2.4), compared with those in the 1983 cohort group (b = 1.7, SED = 0.06). As the allometric coefficient did not differ significantly with sire, differences in the scaling factor indicated a constant multiplicative difference in velvet weight between sires, when adjusted for winter lean liveweight. Taking the antilog of the maximum difference between the least square deviations for sires in Table 2, reveals a maximum multiplicative difference between sire progeny groups of 1.32. That is, when compared at the same liveweight, the progeny of sire number 10 yielded c. 32% more velvet than progeny of sire number 2.

DISCUSSION

The allometric coefficients (b) relating velvet antler weight and winter lean liveweight were 2.4 and 1.7, indicating that for both the 1982 and 1983 year-of-birth cohort groups, velvet antler weight was later maturing than winter lean liveweight. This result was similar to allometric coefficients for hard antler weight and eviscerated body weight for groups of red deer stags, reported by Huxley (1931) and Schröder (1983). In previous studies the coefficients represent the relationship between stags, whereas the current data represent relationships within stags over 3 successive years.

Both antler size and liveweight are important for reproductive success, as they both contribute to the display and fighting prowess that are critical factors in determining the social rank and therefore reproductive success between mature stags (Lincoln 1972; Goss 1983; Clutton-Brock & Albon 1985). It is therefore interesting to speculate on the evolutionary pressures that have given rise to the later-maturing pattern of velvet antler weight

Table 1 Means, standard deviations and range for velvet antler weights and winter lean liveweights for stags born in the 1982 and 1983 cohorts.

Year	Age	Velvet weight (Mean, kg)	SD	Range (kg)	Liveweight (Mean, kg)	SD	Range (kg)
Born 1982 (*n* = 60)							
1984	2 year old	1.23	0.27	0.76–1.91	101.1	6.9	82–123
1985	3 year old	2.05	0.41	1.27–3.47	127.3	7.7	104–143
1986	4 year old	2.59	0.43	1.84–3.99	134.6	7.6	119–157
Born 1983 (*n* = 85)							
1985	2 year old	1.48	0.43	0.73–3.5	105.3	9.6	82–159
1986	3 year old	2.19	0.42	1.36–4.24	124.9	9.9	106–173
1987	4 year old	2.42	0.47	1.59–4.41	141.3	10.1	121–179

Table 2 Least square deviations (± average SE) for sire effects on the scaling factor (log A) and allometric coefficient (b) for the relationship between $\log_{10}$ velvet weight and $\log_{10}$ liveweight, after adjusting for the effect of animal within sire.

	Scaling factor (log A)			Allometric coefficient (b)	
	Constant	Sire	Year of birth	Log liveweight	Log liveweight × year of birth
Log velvet weight	−3.821 (0.131)	1[a] −0.049	1982 −0.763	2.030 (0.060)	1982 0.372
		2[a] −0.060	1983 0.763 (0.140)		1983 −0.372) (0.060)
		3 −0.027			
		4 0.004			
		5 0.049			
		6 0.004			
		7 0.011			
		8 0.013			
		9 0.014			
		10 0.059 (0.038)			

[a]Denotes stags that were common to both years.

relative to liveweight in stags. Liveweight is a cumulative trait and, within a group, a heavier than average immature weight increases the probability of a stag attaining a heavy mature weight (Clutton-Brock et al. 1982; Fennessy et al. 1991). In contrast, antlers are regenerated annually and size of the antler in one season does not necessarily have a direct effect on the size of the antler grown in the following season (Goss 1983). As a result, there would appear to be no apparent advantage for a stag to possess large antlers until it is close to its mature body size, for without the combination of both large mature size and antler size, a stag would have limited chance of reproductive success (Clutton-Brock et al. 1979). A late-maturing pattern for antler weight relative to liveweight within individual stags would be consistent with evolutionary pressures that ensure that the heaviest antlers are produced when a stag is approaching its mature weight.

The multiplicative difference between sires indicates over a 30% difference in velvet antler weight for the same winter lean liveweight. However, as stags were weighed several months before velvet harvest, it is difficult to speculate on the basis for this effect, as it could be the result of sire effects on antler growth, body growth, or a combination of both. It seems likely that there may be genetic variability in the partitioning of nutrients towards maintenance, body growth (primarily the accumulation of body fat; Drew 1985), and antler growth during the spring months. This was reflected in the differences in velvet weights of the different progeny groups after adjustment for winter lean liveweight.

The results indicate that there is likely to be considerable potential to improve velvet antler weights at the same liveweight by selection of superior sires. However, a much larger sample of sires and progeny would be required to obtain reliable estimates of the genetic parameters and assess the potential. Preliminary studies on the inheritance of antler size in sika deer (*Cervus nippon*; Zhou & Wu 1979) indicate that genetic variation exists for velvet antler weight with estimates of the heritability of antler weights being 0.35 and the genetic coefficient of variation being greater then 20%. Genetic variation for liveweight is also apparent in red deer, with heritabilities for weaning and yearling weights ranging from 0.2 to 0.7 (Rapley 1990; McManus & Hamilton 1991). The underlying basis of the relationship between antler and liveweight, particularly between and within subspecies and strains of *Cervus elaphus*, clearly requires further investigation.

Year of birth had a significant effect on the allometric relationship between velvet antler weight and liveweight (Table 2). This difference in the allometric coefficients either reflects the unique sequence of seasons experienced by each cohort group, or differences in the stage of antler removal between years. Unfortunately, no retrospective analysis of these factors is possible. However, the difference does highlight the possible importance of seasonal variation in velvet antler yield and indicates the importance of developing appropriate objective criteria to define the stage of development of the antler at the time of removal. Such criteria would help elucidate some of the important factors involved in variation between years (see Fennessy (1989a, b)). In addition, definition of criteria for velvet antler quality (e.g., calcification and lipid content by the stage of growth; Fennessy & Duncan 1992) will enable assessment of possible underlying variation and this will need to be taken into account in future studies.

Implications

The multiplicative difference between sire groups in the relationship between antler weight and winter lean liveweight suggests that there is genetic variation in the partitioning of nutrients between velvet antler and body tissues. Further research is needed to devise genetic parameters, quantify the extent of the variation, and to define the possibilities for genetic improvement of velvet antler production.

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